VOLUME 80 SEPARATE No. 419

PROCEEDINGS

AMERICAN SOCIETY OF CIVIL ENGINEERS

MARCH, 1954

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

TWIN OPPORTUNITIES: CONSERVATION AND ENGINEERING

by Clarence Cottam

Presented at
Atlanta Convention
February 15-19, 1954

SANITARY ENGINEERING DIVISION

{Discussion open until July 1, 1954}

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

THIS PAPER

--represents an effort of the Society to deliver technical data direct from the author to the reader with the greatest possible speed. To this end, it has had none of the usual editing required in more formal publication procedures.

Readers are invited to submit discussion applying to current papers. For this paper the final closing dead line appears on the front cover.

Those who are planning papers or discussions for "Proceedings" will expedite Division and Committee action measurably by first studying the printed directions for the preparation of ASCE technical papers. For free copies of these directions—describing style, content, and format—address the Manager, Technical Publications, ASCE.

This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

TWIN OPPORTUNITIES: CONSERVATION AND ENGINEERING

Clarence Cottam[1]

INTRODUCTION

Engineers of this country can be justly proud of the giant dams, bridges, tunnels, turbines, skyscrapers, airplanes that triple the speed of sound, and many other mighty monuments to their creative skill and imagination. You have had a large share in shaping the destiny of this Nation, and will continue to do so in the future. However, all that has been accomplished in the past may be simple compared to the problems ahead. It's a task that will give the acid test to America's best engineering brains and skill.

Briefly, the question appears to me to be: Can future generations enjoy the luxuries of a modern mechanized civilization and at the same time continue to share in our unequaled heritage of natural resources which comprise an important part of the "American way of life"? Specifically, will the added millions of Americans continue to enjoy healthful outdoor recreation in hunting and fishing? Or will these biological assets be replaced by soot, silt, and concrete?

One way of solving the problem, of course, is for you to say "That's your worry, not ours." But just as pollution from factories is largely an engineering responsibility, so too are other by-products of engineering accomplishments. Wildlife technicians alone cannot do the job. Teamwork is necessary for success. If this problem is solved satisfactorily for future America, in a very large measure it will be because your profession has put its brains to work on it and because you have cooperated wholeheartedly with the biologists. This problem of cooperation is not a one-way street, but consists of mutual respect and support for each other's problems and responsibilities. It represents a joint attack on related problems.

In the management of most reservoirs, the problems of sanitary engineering and conservation nearly always occur simultaneously, but unfortunately at times have appeared to be diametrically opposed to each other. As workers in both fields have gained more experience, and have honestly attempted to resolve conflicting issues, a far better working relationship has been achieved, and usually a well integrated, coordinated program has resulted to the public betterment.

While there are problems and conflicts still confronting us, and probably always will be, those most competent to judge will usually agree that the areas of agreement and compatibility or mutual benefit now far exceed the areas of conflict. Thus, through advanced, integrated planning and development, we see mutual opportunities for the enhancement of values of multiple-purpose projects.

---

1. U. S. Fish and Wildlife Service.

Conservation Values

The term "conservation" means wise use of our natural resources. In its application to renewable resources such as soil, water, forests, and wildlife, it implies full public use without waste or abuse in a way that will maintain the maximum sustained yield and yet not impair the quality and quantity of our natural resources. It is the kind of use that will insure perpetuity of value and supply for future generations. It does not mean non-use of a resource. In a broad sense, it implies a harmonious balance between man and his environment.

In my judgment, America's resources form the principal basis of our wealth, security, progress, and greatness. Any nation is rich so long as its supply of resources exceeds the people's needs. After that, no nation can be self-supporting. Competition for the necessities of life induces a death struggle among peoples as among the lower forms of life. Anyone who questions this can, with profit, review the history of causes of world conflicts, and the history of the peoples of such lands as Canaan, Babylonia, Persia, Carthage, and east Asia.

America has been more richly endowed by Providence with abundant natural resources than any other land on earth; yet the records indicate that we have been most prodigal in their use. Fortunately, our people are awakening and demanding conservation and wise use of resources. We believe that multiple-purpose projects, especially where water development is concerned, can be fully achieved only when all resource potentials are fully considered in plans for development. Not only must plans be devised to preserve existing resources to the fullest extent possible, but every feasible means for increasing them should be adopted. Coordinated, advanced planning by all interests is essential.

Fish and wildlife are among our great resources which must be preserved and wisely used. During 1952, 14 million persons in the United States bought hunting licenses, and another 17 million purchased fishing permits. Probably another 8 to 10 million who were not required to buy licenses participated in the all-American sport of fishing and hunting. In the pursuit of their favored sport, fishermen and hunters spent somewhere in the neighborhood of 5 to 9 billion dollars, and the food values of the resource obtained in the pursuit of this sport probably ranged from 1/2 to 1 billion dollars. In addition, commercial fish harvests amount to about 4 billion 400 million pounds yearly or a total of 350 million dollars. In addition, the health, recreational, esthetic and spiritual values of wildlife to the American public will equal if not exceed the direct economic or monetary values.

The public demand for sport fishing and hunting is growing by leaps and bounds, and it is certain to continue—barring a National catastrophe, such as war, and providing an adequate game supply and a place to obtain or harvest the resource are maintained. As evidence of the growth of this demand, waterfowl hunting has increased five-fold throughout this Nation in the past 17 years.

National Policy

It is unfortunate that in the past many costly reservoir projects have been planned, constructed, and operated without consideration for sustaining fish and wildlife production. Long ago the public demanded a change in this policy. As an expression of this public sentiment, and to implement this more

enlightened concept, the Congress in 1934, and again by amendment in 1946, passed the Coordination Act (Public Law 732, 79th Congress) to "promote the conservation of wildlife, fish and game." This establishes the National policy and philosophy that fish and wildlife interests be considered as partners in the planning of Federally sponsored and publicly supported multiple-purpose water development projects along with power, navigation, flood control, and irrigation. The Act provides that "Whenever the waters of any stream or other body of water are impounded ... adequate provision consistent with the primary purposes of such impoundment ... shall be made for the use thereof, together with any areas of land, or interest therein, acquired or administered in connection therewith, for the conservation, maintenance, and management of wildlife resources thereof, and its habitat therein. ..."

President Eisenhower, in his special conservation message to the Congress on July 31, 1953, affirmed this as his Administration's policy when he stressed the "... necessity for a cooperative partnership of the States and local communities, private citizens, and the Federal Government in carrying out a sound natural-resources program." He added that "Our basic problem is to carry forward the tradition of conservation, improvement, and wise use and development of our land and water resources." To do this, he felt "will require comprehensive river basin planning with the cooperation of State and local interests." The President remarked that "the people are entitled to expect that their timber, minerals, streams and water supply, wildlife and recreational values, should be safeguarded, improved and made available not only for this but for future generations." He appropriately concluded that "conserving and improving our land and water resources is high priority business for all of us." This National policy of multiple use and coordinated management applies equally to the construction, operation, maintenance, and management of multiple-purpose projects.

Douglas McKay, Secretary of the Interior, in expressing the attitude and policy of his Department in a recent report published in Sports Afield, asserted "It is a challenge to plan necessary developments if fish and wildlife values are to be maintained." ... "The solution lies in preliminary planning. Rather than wait until a crisis faces us and then devise frantic and many times uneconomical measures to salvage impaired resources, we must think and plan in advance." In speaking of water power development before a recent conference of western governors, he stated that "The tendency to regard power development as the paramount factor in resources development is a fallacy. The importance of flood control, navigation, wildlife conservation, and recreation must never be de-emphasized as they have been in previous years. The potential benefits of these developments may in some instances outweigh power, and the new policy is directed toward the preservation of the multiple-purpose idea of resources development."

Cooperative Efforts in Obtaining Reservoir Values for Wildlife

The value of reservoirs for fish and wildlife depends upon many factors, including the physical and chemical conditions and characteristics of the reservoirs, the location, water depth and quality, pre-impoundment conditioning or treatment, availability of habitat including food and cover, and other necessary environmental conditions adjacent to them. Also it is dependent upon the mode and time schedule of water treatment, fluctuation schedule, and type of management including methods and practices employed in reservoir sanitation to control pollution, pest plants, mosquitoes, and other insect pests, and disease

vectors. In short, the wildlife value of any reservoir may be altered immeasurably through proper coordination in planning and management.

In reservoir planning, construction, operations, and management, it is imperative that the biologist and engineer work together. A number of joint studies have been and are now being made, not only to harmonize conflicting viewpoints, but to find ways and means for accomplishing economical multiple objectives. The results have been most gratifying. Since the early days of the Tennessee Valley Authority, independent and joint studies have been conducted, and I believe all groups are now happy with the results attained.[2]

The most difficult problem was to get the diverse and often unsympathetic, if not antagonistic, groups to work objectively and harmoniously together for the public good. Too many engineers of the past were so wanting in biological knowledge and esthetic appreciation that they seemed to feel that a running stream had little value unless its waters were impounded for turning turbines, or diverted for municipal, industrial, or agricultural uses. Indeed, at times it seemed as if they would never be content until all running waters were impounded and all natural lakes, ponds and swamps were drained and converted for other uses. It appeared the good Lord had made a mistake and the engineers must reverse Creation's purposes.

At the same time, the malariologists and sanitary engineers seemed to proceed on the assumption that the chief objective of reservoir management was to control mosquitoes even though such procedures would eliminate the economic and recreational resources of the reservoir. Many wildlife biologists and game managers also were impractical and narrow in their concepts and objectives, and seemed to look at Nature through such a small peephole that they could see only ducks, muskrats, and fish as worthwhile objects of water or marsh management. When these diverse groups began to come together and consider mutual problems, it is quite understandable that at times more heat than light was generated.

The picture today is vastly different, and many procedures have been found that benefit more than one of the diverse interests, or at least they do not cause appreciable injury to the other interests. Many notable contributions along this line have been made by research work conducted by many States and such Federal agencies as the Bureau of Entomology and Plant Quarantine, U. S. Public Health Service, Tennessee Valley Authority, and the Fish and Wildlife Service. Many of the studies have been cooperative, while others have been directed solely by the particular agency stressing its own immediate problem and responsibility.

One of the most praiseworthy and long-continued studies to resolve reservoir management problems and conflicts of interests of power, flood control, navigation, malarial control, and wildlife has been conducted in the Tennessee River Valley by the Tennessee Valley Authority and the Fish and Wildlife Service. At present, the U. S. Bureau of Entomology and Plant Quarantine, the U. S. Fish and Wildlife Service, the New Jersey Fish and Game Commission, the New Jersey Agricultural Experiment Station, the Delaware Agricultural Experiment Station, and the Delaware Game and Fish Commission, are now cooperating in a joint effort to find more effective ways of controlling mosquitoes and other insect pests in coastal impoundments and marshes. Such teamwork cannot help but greatly reduce the area of conflict and generally result in obtaining multiple objectives.

2. Wiebe, A. H., and A. D. Hess. 1944. Mutual Interests of Wildlife Conservation and Malarial Control on Impounded Waters. Jour. Wildlife Mgt. 8(4):275-283.

The Florida State Board of Health currently deserves public commendation and support for its far-sighted "naturalistic" and biological research in an effort to control mosquito and other insect pests and at the same time retain and possibly enhance wildlife resource values of the State. Water-table studies on tidal marshes at Sanibel Island and New Smyrna Beach give every encouragement for success. J. N. Darling, eminent conservationist, cartoonist, and newspaper man and former chief of the U. S. Biological Survey, writing of the Sanibel Island study, states that Dr. Maurice Provost, biologist in charge of research on control, "has tied in with our water management program on Sanibel and made that area a key demonstration project for the State of Florida to our mutual benefit." Darling concluded that everything proposed by Dr. Provost was equally beneficial to waterfowl and the mosquito control program. Here, water control is practiced by the installation of control gates to raise water tables, and the building of artesian wells and connecting ditches and canals to insure a constancy of water flow and control. Also, sloughs and water courses were deepened to maintain water with its killifish and other insect predators. Mosquito breeding had previously been possible largely because of the periodic drying and flooding of mud flats and sloughs.

It is obvious that procedures in water management must be adapted to loca conditions and specific objectives. Consequently, procedures followed and techniques used cannot have equal or universal application. While not necessarily in order of relative importance, the following are some of those procedures that have proved successful in accomplishing some of the objectives of two or more of the diverse groups interested in or concerned with reservoir management: sanitary, hydraulic and civil engineering, mosquito control, wildlife conservation, and agriculture.

Water-level Management

This technique has been used longer and more consistently perhaps than has any other method of malarial control. Depending upon the schedule of water fluctuations to control mosquitoes and related insect pests, it may be highly beneficial or extremely damaging to wildlife interests. On some large reservoirs in the malarial zone, the water schedule has consisted of: (a) An early spring flood surcharge to strand the winter accumulation of drift and flotage. This often coincides with the spring migration of waterfowl and may provide additional waterfowl habitat and food. (b) A relatively constant normal maximum pool level during the period of early spring growth. This holds back the invasion of undesirable marginal vegetation such as willows and othe water-tolerant woody vegetation. (c) Weekly cyclical fluctuations of limited amplitude. (d) A combined use of cyclical fluctuations and recession during the season of anopheline abundance.

A receding water level decreases the amount of vegetative edge in contact with the water surface (intersection line), and permits greater wave action that is inimical to larval development. It also concentrates larvae in the oper water and exposes them to insectivorous fish and other insect enemies. A receding water level or complete drawdown followed by reflooding usually provide effective control against most Culex or house mosquitoes. Under conditions of stabilized water levels, dense growths of marginal vegetation develop, which provide ideal breeding habitat for a number of species of mosquitoes.

Holding back undesirable vegetation by constant high water levels until early or mid-summer favors the growth of the better waterfowl food plants,

and it greatly favors bass and other centrarchid fish which at this season spawn in the shallow water. A progressive early water recession prevents their reproduction. A mid-summer drawdown often exposes extensive mud flats. A number of the more important waterfowl food plants, such as millet and smartweeds, grow in such a situation with a minimum of management. These same duck foods are typical transition species leading to a climax formation, and are poor plant competitors with the more vigorous and obnoxious or less desirable species that require earlier germination and a longer growth period. Waterfowl foods produced by permanent impoundments include submerged and floating aquatics (pondweeds, wigeongrass, naiads, muskgrasses, wild celery, watershield, duckweeds, and waterlilies) and emergent and moist soil species (millets, wildrice, rice cutgrass, smartweeds, arrowheads, burreeds, bulrushes, and other sedges). Agricultural crops such as corn, sorghum, soybeans, cultivated millets and buckwheat grown on exposed or drawdown lands also provide excellent waterfowl feeding when shallowly reflooded.

In many of the turbid, amber-colored or dark-water lakes and ponds, especially in the East and South, a summer drawdown affords perhaps the best opportunity for waterfowl food production. "Dark" waters seldom are very productive of fish or wildlife, and an appropriate schedule of drawdown may greatly favor both mosquito control interests and wildlife. A uniform rhythm of drawdown, or a drawdown improperly timed, may favor undesirable vegetation and be highly damaging to wildlife interests. A favorable drawdown or schedule of water manipulation may make the difference between a practically worthless or a very successful waterfowl area.

Following are suggested sanitation procedures under appropriate conditions for water-level control of impoundments to favor both mosquito control and wildlife interests: (a) Make pre-impoundment clearings of trees, shrubs, brush, and debris to normal high sustained water level. This procedure eliminates flotage and emergent material conducive to anopheline oviposition, and it often favors a more desirable vegetative growth. Fisheries generally are thus favored. (b) Impound to desired depth during the non-breeding mosquito season. Time and degree of mosquito breeding varies with the species of mosquito involved and with latitude and temperature of the water. The least production normally occurs, however, from mid-fall to late spring. (c) Appropriately manipulate water levels as discussed above. Under a complete drawdown, flooding may enhance wildlife values, and is permissible as long as all water has disappeared within the minimum period necessary for development from the egg to maturity. This varies with the water temperature from less than a week to two or three weeks. All mosquitoes require water in which to develop. Although control of mosquitoes through impoundment and sanitation varies with the different species and the particular area under consideration, the one requirement of water level control is advisable in nearly all cases. This is accomplished through provisions for a sufficient inflow of water and an effective means of discharging excess quantities.

Impoundments

Some of our most obnoxious species of mosquitoes, such as Aedes solicitans, A. vexans, and A. dorsalis, and species of Psorophora, and related insect pests lay their eggs only on mud flats of intermittent pools or marshes. The insects hatch after heavy rains or floods which fill the temporary pools. Killifish and other natural insect predators are absent because the pools are

normally dry. Therefore, a managed impoundment is just as effective in the control of this group of insect pests as complete drainage. Impoundments appear to offer the most economical and effective control measure on some coastal and interior marshes. These impoundments, if properly managed, may provide essential waterfowl habitat.

In coastal areas, the joining of backwaters and small, poorly drained areas or intermittently dry pools to a larger permanent impoundment may favor both waterfowl, fisheries, agricultural, and control interests. This prevents the stranding of fish in isolated pools when the water is lowered. Under certain conditions, all interests have found the construction of deep holes or ditches in shallow impoundments also beneficial. This allows top minnows or "mosquito" fish and other natural enemies to enter areas which are not flooded to a great depth, and prevents them from being stranded by receding water levels or being "winter-killed." Impoundments beyond mosquito flight ranges, of course, can be managed solely to promote wildlife interests. The malarial vector, Anopheles quadrimaculatus, normally has a flight range of from half to one mile. As it is entirely nocturnal, human occupancy near a marsh or swamp is permissible if restricted to daylight use. Culex mosquitoes generally range about one mile, but certain species of Aedes, Psorophora, and Mansonia range commonly from four to six miles, and at times travel much further.

Dewatering Projects

On the huge Tennessee and Wheeler Lakes of TVA, a number of extensive dewatering units have been constructed. These areas comprised several thousand acres of highly productive agricultural lands that would be shallowly flooded during floods and high water periods. Malariologists recognized that these areas would constitute their greatest and most costly problems of mosquito control. Agricultural interests were insistent that these lands not be taken out of production. The financial savings from not having to carry on control, and the values of the agricultural crops, made it possible to dike off these productive lands and keep these areas dry during a somewhat reduced summer season through the installation of large pumping plants. During the period of floods and high water of the winter and spring, these dewatering units were shallowly flooded. By regulating the type of crops grown, these areas have become extremely important wintering areas for waterfowl. Thus, the interests of flood control, agriculture, mosquito control, and wildlife conservation are all greatly benefited.

Biological Controls

Management of a reservoir or pond in a way to favor top minnows (Gambusia, Cyprinodon, Fundulus, and Mollienesia) and other mosquito-eating fish is extremely important as a control measure. Maintaining normal maximum pool levels during the spring favors the production of these and other predaceous fish. These fish seem to be particularly important in connection with the use of water level fluctuation where, during recessions, the mosquito larvae are forced from vegetative covering into open water and are exposed to increased predation. Other "naturalistic" means that keep obnoxious vegetation in check and that open up backwater and other isolated pools to top minnows are desirable methods of control.

It is quite necessary to control carp because these bottom feeders root up

aquatic vegetation which forms flotage in which anophelines and other mosquitoes lay their eggs. The carp in their feeding make the water turbid, which greatly cuts down desired aquatic plant growth and therefore reduces wildlife and fish food production.

The reduction or elimination of certain flexuous, floating, and emergent leafy plant species may be in the best interests both of mosquito control and wildlife conservation. Most of these plants generally are of little wildlife value and they have a high anopheline and pest mosquito production potential. Skilled water manipulation, the judicious application of herbicides, and mechanical means of control are at times required to hold these undesirable species in check. Such procedure usually favors the production of a more desirable plant association which in turn favors both the mosquito control and wildlife interests. Experience has shown that nature will not long permit an area to be devoid of plant growth. Therefore, when obnoxious species are removed, the more desirable species should promptly be planted unless they are already present in satisfactory abundance.

There is need for the development of equipment that will make the control of undesirable vegetation more economical. There is need for an amphibious mower that can cut such pest species as cattail, giant cutgrass and sawgrass.

Shoreline Improvement and Maintenance

Experience has clearly demonstrated that the more permanent measures of reservoir shoreline conditioning rather than temporary ones are much more successful and economical in the long run. This includes cutting and filling to eliminate feather edge where malarial control is a necessity. Dewatering and restricting use to daytime occupancy may likewise be considered appropriate maintenance measures. Usually best results are obtained when necessary cutting and filling are carried on as a part of pre-impoundment conditioning. In some of the "fill" areas, agricultural or other waterfowl food crops are grown which greatly benefit wildlife. The cut and fill program tends to reduce the extent and density of marginal vegetation and flotage, and permits an increase of wave action and facilitates entry of larvivorous fish. These measures often decrease food and habitat for waterfowl and are therefore recommended only where control operations require it.

Some Federal refuges have become highly attractive to waterfowl because of the corn, sorghum, soybeans, millet or other waterfowl foods agriculturally produced. When such areas can be shallowly flooded, they become highly attractive to nearly all waterfowl species. Dry fields which grow suitable agricultural crops commonly attract geese, mallards, pintails, widgeons, and coots. Such intensive agriculture greatly increases the carrying capacity of the refuge. This type of wildlife development is commonly practiced and most desirable adjacent to large impoundments that of themselves have limited carrying capacity for waterfowl.

Larvicidal Control

Reasonable control of mosquitoes, black flies, and other insect pests produced along river courses and impounded areas adjacent to human habitation is a prime necessity, and other river programs must not be seriously contrary to this. It is not unreasonable to expect the control program to be so adjusted that it will do the least damage to other interests.

Among the control procedures not heretofore discussed is the judicious

use of insecticides. Because of sensitivity of many forms of aquatic life to DDT and other insecticides, these materials should be used only in emergencies and to the minimum extent necessary. Two-tenths of a pound per acre or less of DDT is recommended for aerial application. For anopheline control, .05 to .10 pound of DDT per acre has proved effective. Smaller quantities of insecticides should be used in emulsions because of the increased toxicity of this formulation to many aquatic animals. Dosages and formulations should be those which have been approved by the wildlife biologists as well as the malariologists in order that desirable forms of wildlife and their food will not be destroyed along with the obnoxious mosquitoes and other pests. Experience has shown that where objective approach is taken, this can be accomplished, but it is imperative to emphasize that in such a situation there is no room for the control worker that takes the point of view that if a little of the control agent is good, more must be better. Naturalistic and biological methods of control should be used as far as possible, but occasionally there will be times when the judicious use of insecticides will be in the public interest, but it must be used with care and understanding of all values concerned.

Pollution

Pollution has too long been considered solely as a public health matter. The damage to wildlife, fisheries, and recreational resources by domestic and industrial wastes is tremendous and alarming. The pollution problem, as it affects public water supplies, and as it affects fish and other aquatic life, is by no means identical or uniform; consequently, abatement problems cannot be resolved by the same treatment or identical programs. Organic wastes from cities are a serious menace to public health, but may serve as a stream or lake fertilizer and not be detrimental to fish unless the volume of decaying sewage is so large as to deplete or dangerously decimate the oxygen content of the water. Conversely, some industrial wastes may not be seriously detrimental to public health, but may be highly toxic to fish and other aquatic organisms. Beatty[3] has shown that "To combine the two, some toxic wastes in dilute quantities and certain non-toxic wastes such as mine dredging refuse, which blanket out the bottom of a stream, may not be detrimental either to aquatic life or public health directly, and yet the water may be practically barren of fish because the pollution blankets out spawning grounds, destroys food-producing vegetation, and prohibits its growth."

It has long been known that many of our more favored game fish cannot survive in "treated" water which the average city dweller drinks, because the chemical treatment usually required to kill pathogenic human bacteria is lethal to most fish that have to live in it constantly. A safe and highly prized stream from a public health standpoint may be a biological desert so far as fish and aquatic organisms are concerned. Conversely, the water of some good fish streams and lakes may not be entirely safe from a health viewpoint.

Silt-laden streams and lakes resulting from soil erosion and poor land practices are another form of pollution that is doing irreparable damage not only to fisheries and other wildlife resources, but to agriculture and the National economy generally. Stream dredging and straightening, or stream erosion, similarly does great damage to our fishery resources. Hydraulic

---

3. Beatty, Robert O. 1948. Wildlife's Stake in Pollution Abatement. Trans. 19th No. Amer. Wildlife Conf., Wildlife Mgt. Inst., Washington, D. C.

and strip mining operations, gold placer mining, and mine tailings washed into streams and lakes do serious damage to fish and other aquatic life both directly and indirectly. According to Beatty (page 568), hydraulic mining operations on the American and Yuba Rivers of California have reduced the spawning areas for salmon and steelhead trout by 44 and 76 percent respectively. This important economic and recreational loss to the American public certainly should be weighed against the more restricted private benefits from the mining operations.

Cannery, paper pulp, sawmill, creamery, brewery, and other organic wastes, along with excessive quantities of organic city sewage dumped into many streams, is serious. The organic sludge often causes an almost complete absence of dissolved oxygen in wide expanses of many rivers and lakes. In streams that contain favorable spawning habitat for anadromous or other migrant fishes such as salmon, shad, and certain trout, an oxygen block is as effective a barrier to upstream migration and spawning as any concrete dam. Vast expanses of many otherwise productive streams are thus made barren of fish and other aquatic life. In most States, pollution has eliminated the choicer game species from many miles of streams, and any survivors are the less desirable pollution-tolerant "trash fish" such as carp, goldfish hybrids, suckers, and bullheads.

In 1948, Pennsylvania estimated (see Beatty, pp. 570 to 576) that between 1,000 and 2,000 miles of its streams were dead biologically, due to pollution. At the same time, New York State showed that 1,260-1/2 miles of its streams had been eliminated from production for the same reason. Illinois estimated that the destruction of fish on 120 miles of the Illinois River in that State had eliminated 7 million pounds of fish (carp, in this instance) annually. Pollution is largely responsible for the elimination of the once important commercial and sport salmon runs on most of the New England rivers. The shad runs have gradually lessened on most of our east coast. From 1887 to 1896, the average annual shad catch was 41,576,300 pounds. In the years 1926 through 1935, only 11,159,200 pounds were produced annually. Much, if not most, of this decline in production is chargeable to pollution.

Recent declines in the production of shad from the Delaware River must be attributed largely to the extensive pollution there. In the latter part of the nineteenth century, catches ranged from 11 million to 19 million pounds per year; whereas in recent years they have been less than 200,000 pounds, and these are taken, not in the river, but out in Delaware Bay. Over-fishing may have been responsible for a small part of this decline, but pollution appears to be the primary factor. Municipal sewage and industrial wastes have caused pollution in the lower part of the river, varying in extent and degree with river flow. In 1946 there was a 50-mile "slug" of heavily polluted water in the lower river. At times the oxygen content in the polluted area falls to zero, at which time no fish can survive or penetrate this barrier.

The Interstate Commission on the Delaware River Basin (Incodel) has made a vigorous attempt to reduce pollution in the river, and many treatment plants have been installed and more are planned. If this abatement program is continued, and if adequate river flows are maintained, it is probable that the shad run may be restored to something approaching its former level of productivity.

Organic sewage helps to create an ideal environment for a number of serious waterfowl diseases. Several severe outbreaks of botulism food poisoning, and fowl cholera have been traced to such pollution centers in a surprising number of States, and much effort has been expended to keep waterfowl away from areas of contamination. Despite efforts to keep birds away

from a seriously contaminated area near Woodland, California, in 1947 some 17,000 waterfowl succumbed to botulism. A similar situation on the Detroit River and in Lake Erie marshes has caused alarming losses for a number of years. Oil well waste and oil sludge and bilge waste from vessels have intermittently caused spectacular losses among waterfowl for many years. Severe losses also have occurred to muskrats, fish, and other aquatic resources.

The number and kinds of industrial and mining pollutants are legion and vary greatly in toxicity and harmful effects. In industrial centers, there is a growing number of air pollutants, along with toxic effluents, dumped into our streams.

There is a pressing need for critical research into the specific effects of pollution on both plants and animals, and still more urgent need for research on means of preventing and abating these varied types of pollution. Certainly a stepped up action program of pollution prevention is needed, and pollution laws with teeth in them are a necessity in many parts of the country.

I agree with Dr. Henry Baldwin Ward[4] on the approach to resolve this complex industrial pollution problem when he said "It is not reasonable to expect the public to solve the individual problems of every business—the steel business, the oil business, the tanning industry, the various chemical corporations (and the municipal sewage plants) have their chemists (and engineers) who understand their practices, know precisely the character of their wastes, and can better determine the way to handle them than any State or government agency."

One of the more interesting experiments in pollution control concerns an attempt at cleaning up the Raritan River and Raritan Bay in New Jersey following phenomenal growth of the Raritan River valley as an industrial area. The operators of a huge titanium plant were restrained from discharging ferrous sulfate (copperas) and sulfuric acid into the Raritan River. Since early in 1948 the company has been barging the wastes out to sea at a rate of about 4,000 tons per day. The disposal area is over the submerged gorge of the Hudson River, chosen because of strong, deep, offshore currents. Discharge of the material is in the turbulent water in the wake of the barge. Very careful, impartial biological, hydrographic, and oceanographic studies have been made of the area since waste disposal at sea began. The acid ferrous sulfate waste reacts rapidly with sea water to form inert materials. Mixing and neutralization of the waste with sea water takes place rapidly and no accumulation of the products has been found. No evidence at all of undesirable effects has been found.

The capacity of our offshore ocean waters to receive and dispose of wastes that have such destructive effects in streams and rivers is very large, provided the waste is of such a character as to be safely treated this way and the disposal area is carefully selected in relation to local hydrographic conditions, and the proximity of fishing grounds.

It is difficult to set up specific minimum standards of purity of either water or air below which pollution should not be tolerated. Perhaps some helpful suggestions concerning water purity may be found in the conclusions of a five-year study of over 5000 fresh-water streams conducted by a group of

---

4. Ward, Henry Baldwin. 1924. Pollution. Proc. 2nd Annual Conv. Izaak Walton League of America, pp. 67-84. Chicago 2, Illinois.

Fish and Wildlife scientists under direction of Dr. M. M. Ellis[5] formerly of the Fish and Wildlife Service.

They concluded that to maintain a satisfactory flora and fauna, a stream must show, among other requirements, the following characteristics:

1. Dissolved Oxygen: not less than 5 ppm. at 25° C.
2. pH: 6.7-8.5
3. Conductivity: 150-500 mho (megohms) X 10^{-6} at 25° C.
4. CO_2 (fixed): 10-40 cc per liter
   (free): less than 2 cc per liter found in 90 percent of the streams surveyed.
5. Ammonia: not to exceed 1.5 ppm.
6. Suspensoids: hardness of 1 or greater, with a millionth light intensity level not less than 5 meters.

The serious and economically wasteful pollution problem calls for a more dynamic, affirmative program by industry and the public generally. Scientists and groups of all professions that have bearing on the problem should work cooperatively for a more satisfactory solution. Every effort to prevent contamination of our water courses by domestic and industrial pollution benefits all public use of an area.

---

5. Ellis, M. M., B. A. Westfall, and M. D. Ellis. 1946. Determination of Water Quality. Fish and Wildlife Service Research Report 9, U. S. Government Printing Office, Washington 25, D.C.

PROCEEDINGS-SEPARATES

The technical papers published in the past twelve months are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

VOLUME 79 (1953)

MARCH: 176(SA), 177(EM), 178(HY), 179(EM), 180(HY), D-123(HY), D-126(ST), D-128(ST).

APRIL: 181(WW), 182(ST), 184(HY), 185(EM), 186(HY), 187(ST), 188(HY), D-135(HY), D-136(ST).

MAY: 189(HY), 190(HY), 191(CP) & (AT), 192(SM), 193(HY), D-129(PO), D-138(CP), D-145(ST).

JUNE: 194(CP) & (AT), 195(SM), 196(CP) & (AT), 197(HY), 198(ST), 199(EM), D-134(HY), D-141(HY).

JULY: [a] 200(SM)[b], 201(ST)[b], 202(EM)[b], 203(SM)[b], 204(AT)[b], 205(EM)[b], 206(ST)[b], 207(SA)[b], 208(SA)[b], 209(ST)[b], 210(SU)[b], 211(EM)[b], 212(SU)[b], 213(IR)[b], 214(HW)[b], 215(SM)[b], 216(ST)[b], 217(ST)[b], 218(ST)[b], 219(ST)[b], 220(SM)[b], 221(HW)[b], 222(SM)[b], 223(EM)[b], 224(EM)[b], 225(EM)[b], 226(CO)[b], 227(SM)[b], 228(SM)[b], 229(IR)[b].

AUGUST: 230(HY), 231(SA), 232(SA), 233(AT), 234(HW), 235(HW), 237(AT), 238(WW), 239(SA), 240(IR), 241(AT), 242(IR), 243(ST), 244(ST), 245(ST), 246(ST), 247(SA), 248(SA), 249(ST), 250(EM)[c], 251(ST), 252(SA), 253(AT), 254(HY), 255(AT), 256(ST), 257(SA), 258(EM), 259(WW).

SEPTEMBER: 260(AT), 261(EM), 262(SM), 263(ST), 264(WW), 265(ST), 266(ST), 267(SA), 268(CO), 269(CO), 270(CO), 271(SU), 272(SA), 273(PO), 274(HY), 275(WW), 276(HW), 277(SU), 278(SU), 279(SA), 280(IR), 281(EM), 282(SU), 283(SA), 284(SU), 285(CP), 286(EM), 287(EM), 288(SA), 289(CO).

OCTOBER: [d] 290(all Divs), 291(ST)[c], 292(EM)[c], 293(ST)[c], 294(PO)[c], 295(HY)[c], 296(EM)[c], 297(HY)[c], 298(ST)[c], 299(EM)[c], 300(EM)[c], 301(SA)[c], 302(SA)[c], 303(SA)[c], 304(CO)[c], 305(SU)[c], 306(ST)[c], 307(SA)[c], 308(PO)[c], 309(SA)[c], 310(SA)[c], 311(SM)[c], 312(SA)[c], 313(ST)[c], 314(SA)[c], 315(SM)[c], 316(AT), 317(AT), 318(WW), 319(IR), 320(HW).

NOVEMBER: 321(ST), 322(ST), 323(SM), 324(SM), 325(SM), 326(SM), 327(SM), 328(SM), 329(HW), 330(EM)[c], 331(EM)[c], 332(EM)[c], 333(EM)[e], 334(EM), 335(SA), 336(SA), 337(SA), 338(SA), 339(SA), 340(SA), 341(SA), 342(CO), 343(ST), 344(ST), 345(ST), 346(IR), 347(IR), 348(CO), 349(SM), 350(HW), 351(HW), 352(SA), 353(SU), 354(HY), 355(PO), 356(CO), 357(HW), 358(HY).

DECEMBER: 359(AT), 360(SM), 361(HY), 362(HY), 363(SM), 364(HY), 365(HY), 366(HY), 367(SU)[e], 368(WW)[e], 369(IR), 370(AT)[e], 371(SM)[e], 372(CO)[e], 373(ST)[e], 374(EM)[e], 375(EM), 376(EM), 377(SA)[e], 378(PO)[e].

VOLUME 80 (1954)

JANUARY: 379(SM)[e], 380(HY), 381(HY), 382(HY), 383(HY), 384(HY)[e], 385(SM), 386(SM), 387(EM), 388(SA), 389(SU)[e], 390(HY), 391(IR)[e], 392(SA), 393(SU), 394(AT), 395(SA)[e], 396(EM)[e], 397(ST)[e].

FEBRUARY: 398(IR)[f], 399(SA)[f], 400(CO)[f], 401(SM)[f], 402(AT)[f], 403(AT)[f], 404(IR)[f], 405(PO)[f], 406(AT)[f], 407(SU)[f], 408(SU)[f], 409(WW)[f], 410(AT)[f], 411(SA)[f], 412(PO)[f], 413(HY)[f].

MARCH: 414(WW)[f], 415(SU)[f], 416(SM)[f], 417(SM)[f], 418(AT)[f], 419(SA)[f], 420(SA)[f], 421(AT)[f], 422(SA)[f], 423(CP)[f], 424(AT)[f], 425(SM)[f], 426(IR)[f], 427(WW)[f].

---

a. Beginning with "Proceedings-Separate No. 200," published in July, 1953, the papers were printed by the photo-offset method.
b. Presented at the Miami Beach (Fla.) Convention of the Society in June, 1953.
c. Presented at the New York (N.Y.) Convention of the Society in October, 1953.
d. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.
e. Discussion of several papers, grouped by divisions.
f. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.